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This report provides projections of the employment of scientists, engineers, technicians, and other occupations for the civilian nuclear industry through the year 2000. Low, medium, and high projections are provided. In all cases, a substantial number of job openings are anticipated to fill needs created by employment growth, retirement, death, and occupational mobility. The expected adequacy of supply to fill these positions is assessed after taking into account projections of college enrollments and degrees along with competing labor demand from nuclear defense, defense waste management, weapons development, non-nuclear defense activities, and other highly technical industries. The likelihood for shortages is high in certain fields. Positions for engineers (particularly nuclear engineers), health physicists, health physics technicians, and electronic technicians will be the most difficult to fill. (Author)

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EXECUTIVE SUMMARY

PERSONNEL REQUIREMENTS, EDUCATION, AND TRAINING FOR CIVILIAN NUCLEAR ACTIVITIES, 1984–2000

Wayne Stevenson

Prepared by

Labor and Policy Studies Program
Manpower Education, Research, and Training Division
Oak Ridge Associated Universities

Prepared for

Nuclear Energy
U.S. Department of Energy

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EXECUTIVE SUMMARY

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Prepared by

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Prepared for

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October 1984

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ABSTRACT

This report provides projections of the employment of scientists, engineers, technicians, and other occupations for the civilian nuclear industry through the year 2000. Low, medium, and high projections are provided. In all cases, a substantial number of job openings are anticipated to fill needs created by employment growth, retirement, death, and occupational mobility. The expected adequacy of supply to fill these positions is assessed after taking into account projections of college enrollments and degrees along with competing labor demand from nuclear defense, defense waste management, weapons development, non-nuclear defense activities, and other highly technical industries. The likelihood for shortages is high in certain fields. Positions for engineers (particularly nuclear engineers), health physicists, health physics technicians, and electronics technicians will be the most difficult to fill.

PREFACE

The Department of Energy's nuclear energy activities are designed to support the technological base needed to continue the industry's development of nuclear power as an economic and environmentally acceptable source of baseload electric power. The Department's Office of Nuclear Energy recognizes the significance of employment and labor supply issues to the success of this effort. Nearly two-thirds of the 227,000 currently employed in civilian nuclear activities are professional or skilled technical workers with formal training or education. Over 25 percent are scientists or engineers as compared to 3 percent for the entire U.S. labor force. The future supply of these highly trained personnel is extremely important not only to the U.S. Department of Energy but also to the nation's training and academic institutions and the nuclear industry.

In spite of the recent growth and the prospects for continued job openings in the future, as documented in this report, many perceive the civilian nuclear industry as declining. Public concern over safety and reports of regulatory problems and power plant cancellations have created misperceptions that may account for declining enrollments in nuclear engineering and health physics, fields of vital importance to the nuclear industry. This situation raises concern about the future labor supply in these and other occupations necessary to the industry. The concern is heightened by projections of high competing labor demands from defense-related activities (nuclear and non-nuclear) and other industrial activities (particularly in electronics and other highly technical industries) and by a declining college-age population through the mid-1990s. This report addresses these concerns and provides a base of planning data that can be used by affected groups.

U.S. Department of Energy/Nuclear Energy recognizes the significance of these employment and labor supply issues for the future of the civilian nuclear industry. In response to these needs, the work reported here documents the employment and educational needs of the industry so that policymakers, industry, and academia have an adequate base of information to guide decisionmaking.

Three alternative futures were assumed in projecting employment, education, and training needs for the civilian nuclear industry. High, medium, and low cases are identified. The medium case closely corresponds to the mid-case of

nuclear energy activity specified by the Energy Information Administration/DOE and the Office of Policy, Planning, and Analysis/DOE. The low and high case projections are designed to show the sensitivity of future employment levels to alternative development paths for the industry. The differences in these cases are carefully defined in the report.

This study was directed by Andrew Millunzi of the Office of Nuclear Energy, DOE. A large number of people in government, academia, and the nuclear industry contributed to the planning and execution of the work. Representing the American Nuclear Society, Manning Muntzing (past president) and Professor Richard Lahey (Rensselaer Polytechnic Institute) were helpful in reviewing the scope and contents of the study and providing comments to help insure that the results would be presented in a form useful to the academic and industrial communities. Octave DuTemple and other ANS staff were helpful in supplying information and in providing valuable contacts in the nuclear industry. Norm Seltzer and June Chewning, Office of Energy Research/DOE, provided review and insight into the project's development and cooperated to ensure that the occupational employment data necessary to the analysis were available on a timely basis. Dr. Paul J. Turinsky, North Carolina State University, Dr. M.J. Ohanian, University of Florida, and Stephen Reynolds, University of Utah, provided helpful comments on an early draft. The study relied heavily on the *Survey of Occupational Employment in Nuclear-Related Activities* conducted in 1983 and earlier years under the management of the Manpower Assessment Program/Office of Energy Research, DOE and its predecessor agencies. These employment data are maintained for DOE by Oak Ridge Associated Universities.

EXECUTIVE SUMMARY

INTRODUCTION

The nuclear energy activities of the U.S. Department of Energy are designed to provide the technological base to support industry's efforts to continue the development of nuclear power as an economic and environmentally acceptable source of baseload electric power. To support this effort the industry will need a continuous flow of scientists, engineers, and other technical workers. Based on known employment patterns and projected developments in the nuclear industry, job openings in civilian nuclear-related activities are expected to grow throughout the 1980s and the 1990s. Between 1990 and 2000 an average of over 10,000 job openings per year will have to be filled in the civilian nuclear industry. Under high growth assumptions, the number of openings per year could approach 25,000 by the end of the century. The greatest number of openings is anticipated among electrical, mechanical, and nuclear engineers and among engineering technicians and reactor operators.

After a decade of fairly rapid growth, current employment in civilian nuclear activities has leveled off at about 227,000. Employment projections for the industry are based on (1) what is known about personnel requirements for the range of activities listed in Figure S-1 and (2) varying forecasts of nuclear-related business activity as summarized in Figure S-2. As described in Figure S-3, employment projections vary according to the growth scenario--low, medium, or high--applied to the industry:

- In the medium case, employment remains fairly stable through the 1980s and then resumes its growth, although at a slower rate than experienced in the 1970s.
- Led by new nuclear power plant orders, the high case shows continued employment growth with employment exceeding 250,000 by 1990 and reaching over 330,000 by the end of the century.
- When low growth is assumed in all segments of the industry, the number employed declines 20 percent by 1990 and then remains fairly stable through the year 2000.

FIGURE S-1. PRINCIPAL ACTIVITIES IN THE CIVILIAN NUCLEAR INDUSTRY

Uranium Mining and Milling

Uranium Fuel Processing, Enrichment, Fabrication, and Civilian Waste Management

Nuclear Reactor Operation and Maintenance

Nuclear Reactor Engineering and Manufacturing

Nuclear Facilities Architectural Engineering and Design

Design and Manufacture of Nuclear Instruments, Gauges, and Control Devices

Nuclear-Related Research and Development
- Nuclear Fission and Fusion Energy-Related R&D
- Nuclear-Related Environmental, Ecological, Biological, and Medical R&D
- Accelerator R&D

Other Activities
- Transportation
- Commercial Laboratory Services
- Health Physics and Industrial Safety Services
- Industrial Radiography
- Security Services
- Special Training
- Laundry and Decontamination Services
- Radioisotopes Production
- Local, State, and Federal Government
- Consulting and Other Miscellaneous Supporting Services

NOTE: For the purpose of this analysis, employment in the following activities is not included in the civilian nuclear industry: Weapons Development and Production, Defense Waste Management. Universities, Hospitals, Other Medical Facilities, and purely Construction-Related Activities.

FIGURE S-2. PRINCIPAL ASSUMPTIONS AFFECTING PROJECTED MANPOWER FOR THE CIVILIAN NUCLEAR INDUSTRY

Energy Information Administration (1983), official DOE low, medium, and high projections of domestic and foreign nuclear generating capacity are assumed.

U.S. share of world architectural engineering business and reactor sales ranges between the current level as a high and no new business as a low.

Redesign, betterment, and backfit (R/B/B) work or support engineering for operating plants constitutes between 15 and 25 percent of architectural engineering and reactor vendor work for 1983 and is related to future power plant capacity expansion.

Imports of uranium concentrate range between 5 and 50 percent of the low, medium, and high estimates of uranium concentrate requirements as derived from Grand Junction Office/DOE projections.

Employment requirements for uranium enrichment activities reflect the range of enrichment options under consideration by DOE as of March 1984.

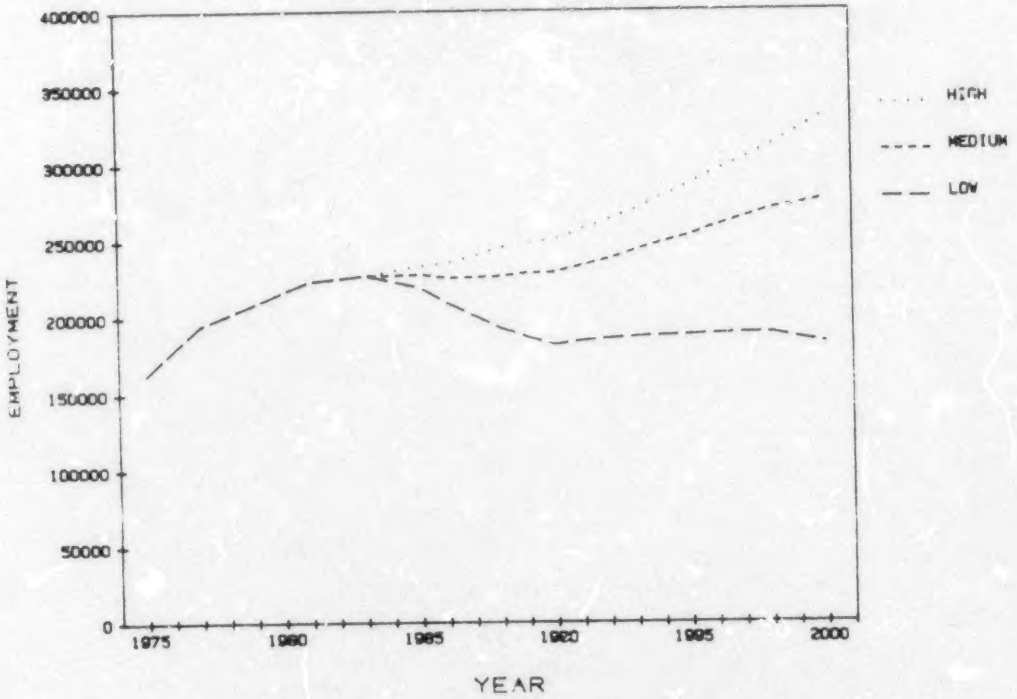
Employment in uranium processing, conversion, and fuel fabrication are related more closely to production capacity than to direct requirements for uranium fuel.

Commercial nuclear waste activities are based on the program plan and guide developed by the Office of Civilian Radioactive Waste Management.

For nuclear-related R&D employment, projections are based on DOE funding estimates through 1989, after which employment projections are consistent with constant funding levels through the end of the century.

NOTE: These assumptions reflect the range of possibilities as discussed in detail in Section VI of the report.

FIGURE S-3.
PAST AND PROJECTED EMPLOYMENT
IN CIVILIAN NUCLEAR ACTIVITIES
1975 - 2000



HIGH CASE: The high case corresponds to the rapid growth outlook for the nuclear industry. Domestic and foreign nuclear generating capacity follow the DOE/EIA (1983a) high projection; uranium concentrate imports hold constant at about 5 percent of domestic requirements; reactor manufacturers and nuclear architectural engineering firms maintain their current shares of world business; and all segments of the nuclear industry grow at their respective "high" rates.

MEDIUM CASE: The medium case corresponds to the middle about which the range of outcomes falls. Domestic and foreign nuclear generating capacity follow the DOE/EIA medium projection; uranium concentrate imports increase to 25 percent of domestic requirements; reactor manufacturers and A/E firms maintain their current shares of world business; and all segments of the nuclear industry grow at their respective "medium" rates.

LOW CASE: The low case corresponds to the slow growth outlook for the nuclear industry. Domestic and foreign nuclear generating capacity follow the DOE/EIA low projection; uranium concentrate imports increase to 50 percent of domestic requirements; reactor manufacturers and A/E firms receive no new foreign business; and all segments of the nuclear industry grow at their respective "low" rates.

Of greatest importance to future civilian nuclear-related employment are

- growth of domestic nuclear generating capacity
- growth of foreign nuclear generating capacity
- the share of foreign power plant-related design/engineering/manufacturing work done by U.S. firms

Engineers, scientists, technicians, managers, and other professionals will continue to comprise about 66 percent of civilian nuclear employment as compared to 26 percent for the entire U.S. work force.

The findings summarized above are discussed in detail in the full report, which contains extensive tables that give employment projections by occupational category.

THE PROJECTED NUMBER OF JOB OPENINGS

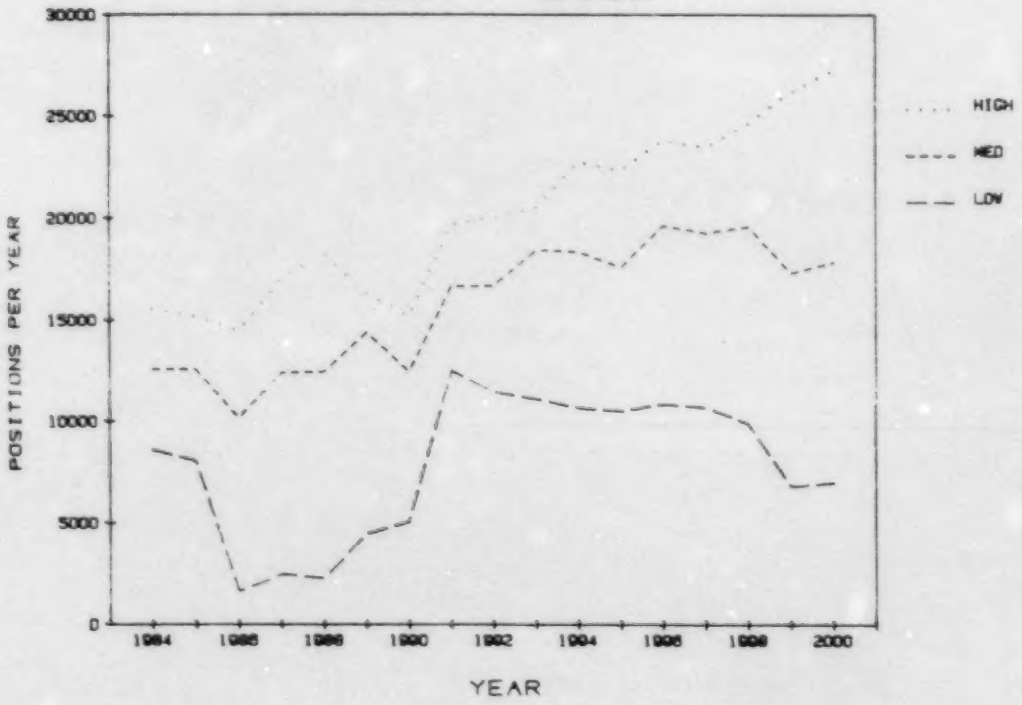
Projected employment requirements, when combined with information on job turnover, provide estimates of the number of positions to be filled each year. Figures S-4 and S-5 summarize the results of such an analysis for the civilian nuclear industry. Some of the major findings concerning annual job openings are summarized below:

- Through the remainder of the century, the greatest number of civilian nuclear-related job openings will result from job turnover due to death, retirement, and especially occupational mobility.
- Except in the low case, the number of job openings per year shows an upward trend for the industry through the year 2000.
- The greatest number of job openings are expected for electrical/electronics engineers, mechanical engineers, nuclear engineers, electronics technicians, health physics technicians, and reactor operators.
- The annual job openings for chemists, physicists, and other scientists in the nuclear industry are comparatively low and fairly stable through the end of the century.

THE PROSPECTS FOR VARIOUS NUCLEAR ACTIVITIES

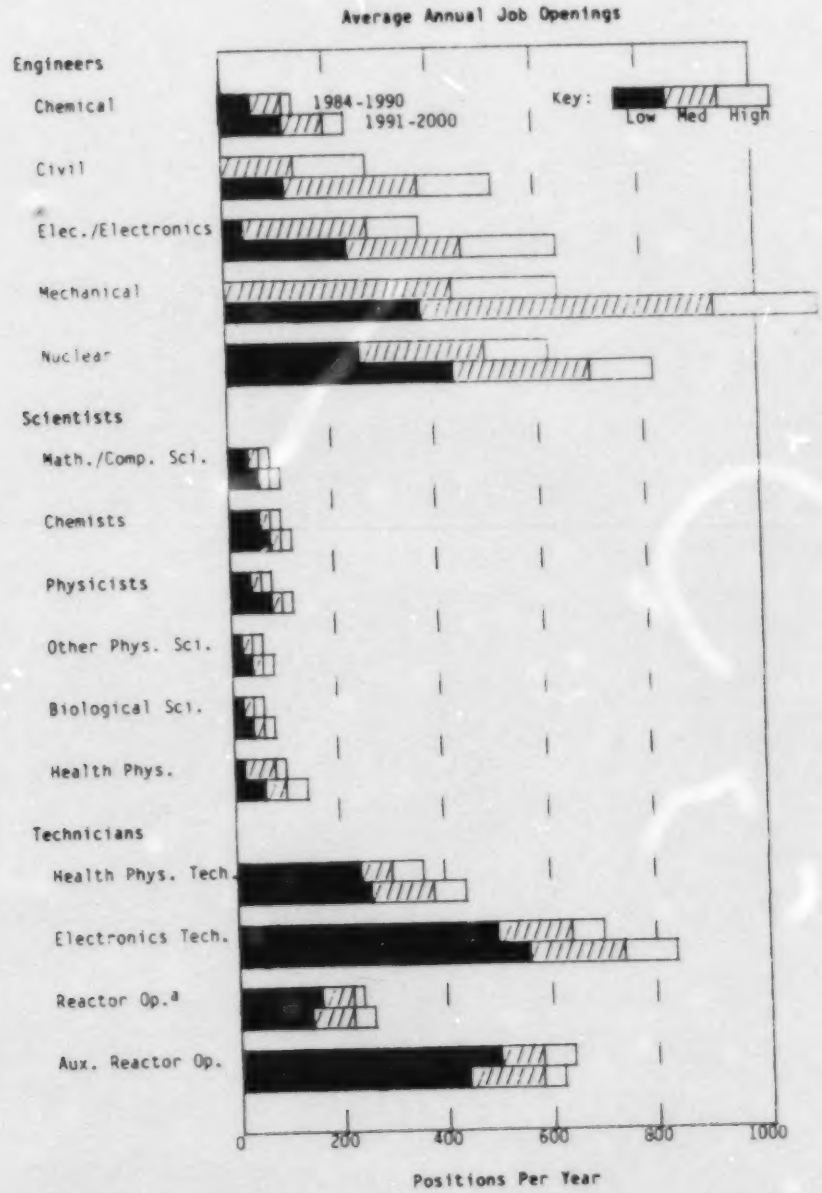
Viewing the civilian nuclear industry as a whole obscures some important changes taking place in different segments of the industry. Employment growth in one activity can mask declining employment in another, leaving a distorted

FIGURE S-4.
PROJECTED JOB OPENINGS:
CIVILIAN NUCLEAR ACTIVITIES
1984 - 2000



NOTE: The number of job openings per year is computed from what is known about job turnover due to death, retirement, or occupational mobility plus or minus any change in the number of positions arising from employment growth or decline.

FIGURE S-5. PROJECTED JOB OPENINGS FOR SELECTED OCCUPATIONS IN THE CIVILIAN NUCLEAR INDUSTRY, 1984-1990 AND 1991-2000



[a]Includes senior reactor operators and reactor operators.

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impression of the overall situation. Highlighted below are some of the most important findings that result from analyzing various nuclear industry activities separately:

The greatest employment uncertainty is in activities related to power plant design, engineering, and manufacturing.

- Nuclear Reactor-Related Design and Manufacturing. Estimated 1983 employment of 19,000 is 50 percent below its 1977 peak. Whether this declining trend continues or reverses depends primarily on the growth of domestic and foreign nuclear generating capacity, the ability of U.S. vendors to attract foreign business, and the need for support engineering work to service existing reactors. Employment could continue to drop to below 5000 by the year 1990, or under high growth conditions it could grow to 25,000 by the year 2000.

- Design and Engineering of Nuclear Facilities. Estimated 1983 employment in architectural engineering and design work for nuclear facilities numbered about 36,000. If no new nuclear power plants are ordered, employment could fall to below 10,000, where it would remain to accommodate support engineering work on existing plants. With new plant orders and growing domestic and foreign nuclear generating capacity, employment would grow during the 1990s, reaching a level between 44,000 and 61,000 by 2000.

Employment related to nuclear power production and nuclear-related R&D is more predictable, at least through 1990.

- Reactor Operation and Maintenance. Estimated 1983 employment of approximately 55,000 will grow to between 65,000 and 72,000 by 1990, beyond which employment requirements are very uncertain. Employment is unlikely to fall, and it could rise to over 85,000 by the year 2000. Actual employment will depend on growth in generating capacity and the rate at which new plants are brought into operation and old plants are decommissioned.

- Fuel Cycle Activities. Estimated 1983 employment of 15,500 in various fuel cycle activities can be expected to show little variation through the late 1990s. What variation occurs will be tied to the closing of one or more gaseous diffusion plants and the opening of new uranium enrichment facilities. Before or after the end of the century, a significant drop in employment will occur as the gaseous diffusion technology is phased out.

- Uranium Mining and Milling. Estimated 1983 employment in uranium mining and milling activities numbered about 9000, down considerably from a 1977 peak of about 11,000. Future power plant refueling activities will keep employment from dropping below 7500, but above this level employment is very sensitive to projected growth in domestic nuclear generating capacity and the level of foreign sales. Under high growth conditions, employment in uranium mining and milling would reach 20,000 by the year 2000.

- Nuclear-Related R&D Activities. Estimated 1983 employment in nuclear-related R&D activities was about 31,500. Based on projected federal funding, this employment is expected to decline somewhat over the next couple of years. Although responsive to changes in R&D expenditures, employment in nuclear R&D activities is currently expected to remain stable at about 27,500 through the remainder of the century.

In addition to the employment noted above, another 53,000 workers were employed in a wide range of supporting activities in 1983. Some of these activities are related to power plant operations, some are related to power plant and reactor design and engineering work, and some are related to other specific nuclear industry activities. On the whole, this supporting employment will grow or decline at a rate consistent with that of the rest of the civilian nuclear industry.

THE ADEQUACY OF FUTURE LABOR SUPPLIES

In attracting qualified personnel, the civilian nuclear industry must compete with the full range of industries operating in large regional or national markets. So to assess likely changes in labor market conditions for the industry, it is necessary to take into account not only changes in the industry's personnel requirements and job openings but also competing demand from other industries and expected trends among future graduates and experienced workers. Over the next decade or so, the greatest competing demand can be expected from nuclear defense, defense nuclear waste, weapons development, and other defense-related activities. Electronics, robotics, office automation, and other "high-tech" industries will all create competing demand in nondefense activities. On the supply side, school enrollment trends, the declining college-age population, and fewer new labor force entrants will all affect the market for engineers, scientists, and technicians.

Table S-1 summarizes the expected net effect of all these factors on the labor market from the perspective of the civilian nuclear industry. Some of the important findings are highlighted below.

For Engineers:

- Current supplies of engineers are generally adequate with some shortages of Ph.D. nuclear engineers.

- Little change in conditions is expected through the remainder of the 1980s.

TABLE S-1. SUMMARY OF CURRENT AND PROJECTED LABOR MARKET CONDITIONS FOR VARIOUS OCCUPATIONAL GROUPS IN THE CIVILIAN NUCLEAR INDUSTRY

Occupation	Current Conditions	Projected Conditions	
		1984-1990	1991-2000
Ph.D. Engineers			
Nuclear	**Some Shortages**--Current demand met by paying comparatively high salaries and by relying on foreign nationals and experienced engineers working in non-nuclear activities.	**Little Change**--Some shortages will continue as the number of nuclear industry job openings remains about the same and enrollment trends suggest no significant increase in the number of new graduates.	**High Potential for Shortages**--A significant increase in the number of nuclear industry job openings without a substantial increase in Ph.D. program enrollments and degrees will greatly increase the likelihood of shortages.
Chemical Elec./Electronics Mechanical	**Generally Adequate Supplies**--Job openings are more easily filled than in early 1980s. Current demand met by paying comparatively high salaries and by relying on foreign nationals and experienced engineers working in non-nuclear activities, many without formal nuclear training or previous nuclear-related experience.	**Little Change**--Job openings in the nuclear industry remain relatively low, but shortages may develop due to competing demand in other industries.	**Increasing Likelihood of Shortages**--A significant increase in the number of nuclear industry job openings is expected at a time when competing demand is expected to be high, particularly among mechanical and electrical engineers.
Civil		**Little Change**--Generally adequate supplies should continue because competing demand is not as great as in other engineering fields and the number of nuclear industry job openings to be filled is low.	
M.S./B.S. Engineers	**Generally Adequate Supplies**--Job openings are more easily filled than in early 1980s although salaries are comparatively high and many positions are filled by experienced engineers, many without formal nuclear training or previous nuclear-related experience.	**Little Change**--Supplies should be generally adequate because the number of nuclear industry job openings remains low. Competition from defense, electronics, and other industries is likely to be high, keeping salaries relatively high.	**Increasing Likelihood of Shortages**--Nuclear industry will stabilize or return to growth while strong competing demand from defense and electronics industries continues, especially for nuclear, elec./electronics, and mechanical engineers.

TABLE S-1. SUMMARY OF CURRENT AND PROJECTED LABOR MARKET CONDITIONS FOR VARIOUS OCCUPATIONAL GROUPS IN THE CIVILIAN NUCLEAR INDUSTRY
(Continued)

Occupation	Current Conditions	Projected Conditions	
		1984-1990	1991-2000
Ph.D. Scientists			
Health Physics	**Some Shortages**--Number of nuclear industry positions has grown rapidly and competing demand from academic and medical institutions has been high, while the number of degrees granted has declined in recent years.	**High Potential for Shortages**--The number of nuclear industry job openings is expected to grow at a time when competing demand from academic and medical institutions is high, resulting in shortages unless the supply of new graduates increases significantly.	
Math/Comp. Sci.	**Some Shortages**--Competing demand and salaries are high, but the number of job openings in the nuclear industry is low.	**Little Change**--Some shortages are expected to continue as competing demand remains high. The number of nuclear industry job openings remains small, however, resulting in few problems for the industry.	
Physical Sciences	**Generally Adequate Supplies**--Competing demand is not unusually high and number of job openings in the nuclear industry is low.	**Little Change**--Supplies are expected to remain generally adequate. Competing demand is not expected to be unusually high and the number of nuclear industry job openings to be filled will remain low.	
Life Sciences	**Generally Adequate Supplies**--Competing demand is not high and number of job openings in the nuclear industry is low.	**Increasing Likelihood of Shortages**--While the number of nuclear industry job openings is expected to remain low, competing demand for life (and biological) scientists is expected to be significantly greater.	
M.S./B.S. Scientists			
Math/Comp. Sci. Physical Sci. Life Sciences	**Generally Adequate Supplies**--Competing demand is not high and the number of job openings in the nuclear industry is low.	**Little Change**--Supplies should remain generally adequate as the number of nuclear industry job openings will be less than 1 percent of the expected number of degrees granted and competing demand is expected to be moderate.	
Health Physics	**Some Shortages**--Number of nuclear industry positions has grown rapidly and competing demand from medical and other industrial activities is high.	**High Potential for Shortages**--Increasing nuclear industry job openings and growing competing demand from medical and other industrial activities will result in shortages unless enrollments and degrees increase significantly.	

TABLE S-1. SUMMARY OF CURRENT AND PROJECTED LABOR MARKET CONDITIONS FOR VARIOUS OCCUPATIONAL GROUPS IN THE CIVILIAN NUCLEAR INDUSTRY
(Continued)

Occupation	Current Conditions	Projected Conditions	
		1984-1990	1991-2000
Technicians			
Electronics Tech.	**Some Shortages**--Competing demand is high resulting in relatively high salaries and some shortages.	**High Potential for Shortages**--Competing demand from defense and electronics industry may result in shortages throughout the economy.	
Health Phys. Tech.	**Some Shortages**--Number of nuclear industry positions has grown rapidly and competing demand from medical and other industrial activities is high.	**High Potential for Shortages**--Increasing nuclear industry job openings and growing competing demand from medical and other industrial activities is likely to create shortage situations.	
Reactor Operators	**Generally Adequate Supplies**--After very rapid growth in the early 1980s, utility and contractor training has kept pace with rapidly growing number of job openings.	**Little Change**--Supplies should remain generally adequate with new operators receiving utility or contractor training.	
Other Technicians	**Generally Adequate Supplies**--Training has generally kept pace with demand throughout the economy.	**Little Change**--Supplies should remain generally adequate throughout the economy.	

- During the 1990s, the likelihood of shortages increases, with a high potential for shortages of Ph.D. nuclear engineers.

For Scientists:

- Some shortages currently exist for health physicists and mathematicians/computer scientists, otherwise supplies are generally adequate.

- With the exception of health physicists where the potential for future shortages is high, little change in conditions is expected through the year 2000.

For Technicians:

- Currently, supplies are generally adequate with some shortages for electronics technicians and health physics technicians.

- With the exception of electronics technicians and health physics technicians where the potential for future shortages is high, little change in conditions is expected through the year 2000.

THE PROSPECTS FOR VARIOUS GEOGRAPHICAL REGIONS

Current employment in the civilian nuclear industry is not evenly distributed geographically. New York, Pennsylvania, New Jersey, and the New England states account for 27 percent of the industry's employment. About two-thirds of all the jobs in the industry are found east of the Mississippi River. While for the nation as a whole about 240 out of every 100,000 jobs are found in the civilian nuclear industry, the rate is 600 per 100,000 in New England.

Regions are not likely to be affected the same by future developments in the nuclear industry. The region made up of New York, New Jersey, and Pennsylvania is most influenced by reactor and power plant design and engineering and operations activities. Uranium fuel cycle activities and reactor operations predominate in Kentucky, Tennessee, Mississippi, and Alabama. In the West, most civilian nuclear industry employment is reported in research and development activities, particularly in the states of California and Washington. Some other specific findings are listed below:

- While 22 percent of the civilian nuclear industry's engineering openings are expected on the West Coast, this region produces only 13 percent of all engineering graduates.

- For nuclear engineers, 26 percent of the job openings are expected to be found on the West Coast while the region produces only 8 percent of the graduates. The regional mismatch is especially noteworthy because the field has experienced a 26 percent decrease in degrees granted nationally since 1977.

- For science occupations, the western states will account for about 37 percent of all civilian nuclear industry positions to be filled but only about 15 percent of all science graduates.

- In health physics, 65 percent of the projected job openings are in Atlantic Coast states while the region only produces 43 percent of the health physics graduates.

So unless enrollment and degree trends change considerably, filling job openings in certain fields will require nuclear industry employers in some regions to (1) rely more heavily on experienced workers rather than new graduates, (2) attract new graduates from other regions, or (3) attract an increasing share of the region's science and engineering graduates. For some regions, the mismatch between job openings and new graduates could increase the potential for future personnel shortages.

CONCLUSIONS

Even in the low growth case, the number of job openings in the civilian nuclear industry is expected to be significant. In the medium and high growth cases, the employment of engineers, scientists, and technicians in nuclear activities may increase more rapidly than anticipated growth in other sectors of the economy during the 1990s. Given high levels of competing demand for engineers (particularly nuclear engineers), health physicists, and electronics technicians along with a declining college-age population, the likelihood is high for shortages to develop in certain key occupations. The regional mismatch between job openings and the supply of new graduates could add to the potential for shortages in some regions. To avoid bottlenecks and potentially costly shortages for the civilian nuclear industry, the employment situation will have to be carefully monitored in the future. Where the potential for shortages is high, it may be appropriate to consider actions aimed at increasing the likelihood of qualified engineers, scientists, and technicians choosing careers in the civilian nuclear industry.

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